NATIONAL BUREAU OF STANDARDS REPORT

6398

QUARTERLY REPORT

ON

EVALUATION OF REFRACTORY QUALITIES OF

CONCRETES FOR JET AIRCRAFT WARM UP, POWER CHECK,

MAINTENANCE APRONS, AND RUNWAYS

by

W. L. Pendergast, E. C. Tuma, L. E. Mong

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U. S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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NBS PROJECT		NBS REPORT
0903-20-4428	April 30, 1959	6398

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Sponsored by

Department of the Navy
Bureau of Yards and Docks

Reference: NT4-59/NY 420 008-1
NBS File No. 9.3/1134-C

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1. INTRODUCTION

The purpose of this project is the development of criteria for the fabrication of jet exhaust resistant concretes. Concretes under development are evaluated by exposure to hot gases from a combustion chamber. The combustion chamber delivers these gases at velocities and temperatures approaching field conditions.

2. ACTIVITIES

2.1 X-ray Examinations of Neat Cements

The examinations of the neat Portland and Lumnite cement pastes after heating under saturated steam pressure to approximately 300°C and also after further heating at atmospheric pressure at increasing temperatures to 800°C have not been completed.

2.2 Blast Furnace Slag Concrete

A batch of concrete designed with blast furnace slag and Portland cement was mixed during the period covered by this report. The properties of the fresh concrete were as follows:

Proportion, by weight, of cement, to fine, to coarse aggregate	1:1.36:2.04
Cement Content sacks/yd^3	7.65
Vinsol resin, by weight of cement, percent	0.01
Water content, gallons/yd^3	35.2
W/C ratio by weight	0.41
Air content, percent	4.7
Slump, inches	2.0
Remarks	Harsh, but placeable

The design was the same as that used for P-BF-3 appearing in Table II of NBS Report 6269 except that Type I Portland cement was substituted for Type III. Panels 18x18x6 inches in size, 6x6x36 inch beams, 3x4x16 inch prisms, and 8x8x1 inch thermal conductivity specimens were fabricated and cured for 28 days in the fog-room. The panels, beams, and one set of prisms were sealed on all but the top surface (as cast) upon removal from fog-room. A moisture-proof plastic (polyethylene) envelope taped in place was used as a seal. All specimens were then dried at 50% relative humidity and 73°F for various periods of time before testing.

2.2.1 Panels

One panel was subjected to the jet impingement test after 21 days drying, and a second panel after 28 days. The jet blast had no apparent effect on either of these panels.

The loss in weight during the test was 0.32% and 0.15% respectively, which could be attributed to water loss. A third panel, after 35 days drying was exposed to the equivalent of a two inch rainfall over a period of 24 hours and immediately subjected to the jet test. During the wetting, the panel increased in weight 0.50%, but decreased 0.48% during the jet impingement. This panel showed no explosive spalling. Thermocouple measurements of temperature in this panel indicated that the presence of the water from the rainfall treatment did not affect the temperature gradient as compared with the gradients found in unwetted panels.

2.2.2 Beams

The length of these beams, 36 inches, permitted two flexural strength determinations to be made on each beam, using an 18 inch span. One end of each of the six beams was broken in flexure; two after 21 days drying, 2 after 28 days, and two after 35 days. Immediately after breaking the remaining section of each beam was subjected to the jet blast and then broken in flexure. Results of these tests appear in Table I.

Table I. Effect of Jet Impingement on Strength of Blast-Furnace Slag Concrete

Laboratory 1/ Identification	Drying period 2/ before Testing days	Exposure to 3/ jet impingement before flexural test minutes	Flexural Strength psi	Type of Failure
P-BF-3-1A	14	none	570	aggregate fracture
P-BF-3-1B	14	10	200	do
P-BF-3-2A	21	none	600	do
P-BF-3-2B	21	10	180	do
P-BF-3-3A	28	none	610	do
P-BF-3-3B	28	10	145	do

1/ The design of the concrete used in fabricating these beams is given in the text, Part 2.2 Blast Furnace Slag, and it also appeared in Table II of NBS Report 6269 identified as P-BF-3. The last numeral 1, 2 or 3 identifies the set of specimens. The last letter A or B denotes the portion of the same beams broken in transverse tests.

2/ Drying period at 50% relative humidity and 73°F.

3/ The beams were positioned at right angles to the jet stream with Top surface (as cast) exposed directly to jet blast.

2.2.3 Prisms

The 3x4x16 inch prisms were tested for flexural strength after the same drying periods as the beams. For comparative purposes one set of prisms was sealed on all but the top surface (as cast) during the drying period, the second set was not sealed. The results of these tests appear in Table II.

2.3.1 Discussion of Beam Tests

During the jet impingement tests the jet blast was directed perpendicular to the top surface, as cast, the beam resting on its side. In the flexural test the loading was at right angles to this direction.

Tests have indicated that during jet impingement, temperature approaching 500°C extend approximately one-half inch below the test surface. Early work in this project has shown that exposure to 500°C for five hours lowered the flexural strength by approximately 50%. Assuming an extreme case of total loss in strength in one inch of the beam depth, a 15% loss in flexural strength might be expected but not a 65% loss.

Table II. Effect of Moisture Sealing, During Drying Periods on Flexure Strength of Concrete Prisms

Laboratory[1/] Identification	Drying[2/] Period	Loss of Weight[3/] During Drying	Flexural Strength	Type of Failure
	days	%	psi	
P-BF-3	21	1.00	485	aggregate fracture
P-BF-3-S	21	0.19	585	do
P-BF-3	28	2.17	560	do
P-BF-3S	28	1.00	575	do
P-BF-3	35	2.29	535	do
P-BF-3S	35	1.14	635	do

1/ These specimens were fabricated from the same batch of concrete as those appearing in Table I. The letter S denotes the set of specimen sealed during drying.

2/ Prisms were dried at 50% relative humidity and 73°F.

3/ Based on weight out of fog-room, attributed to loss of water.

The beams developed macroscopic cracks at the top and bottom surface from which water (perhaps condensed steam) bubbled out during the test. See Figure 1. No cracking was visible on the face exposed to the jet or on the opposite face. In the subsequent flexure test the break occurred in a section containing the two cracks.

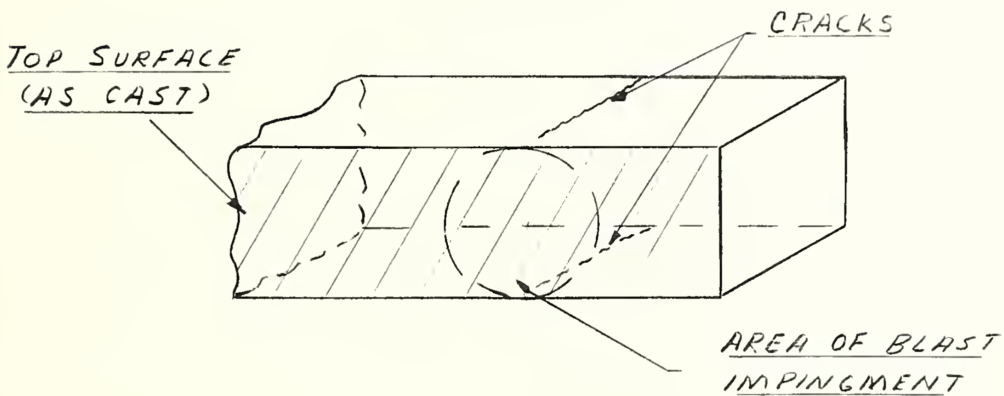

FIGURE 1 LINE DRAWING OF PORTION OF BEAM SUBJECTED TO JET BLAST

Figure 1. LINE DRAWING OF PORTION OF BEAM SUBJECTED TO JET BLAST

Since in an airfield slab the load and the jet blast are applied on the same surface the loss in strength shown by the tests in Table I is probably not indicative of what would result in actual practice.

It is planned in future tests for the evaluation of the strength loss due to rapid heating to apply the load in a direction parallel to the jet impingement even though this involves capping of the test specimen prior to making the flexure test.

The observed cracking was possible due to stresses produced by differential thermal expansion, steam pressure generated, or a combination of both. In an attempt to assess the part played by each of these factors, specimens will be slowly dried at successively increasing temperatures until moistures equilibrium at 110°C is achieved. Presumably jet impingement on specimens in this condition will not involve appreciable forces due to steam pressure.

2.3.2 Discussion of Prism Tests

The 3x4x16 inch prisms, sealed on all but one surface, showed higher flexural strength than those not sealed, after the 21, 28 and 35 day drying periods and suffered less loss in water during the drying periods.

2.4.1 Examination of Aggregate

The characteristics of aggregate that are significant in their performance in heat resistant concrete are being studied.

2.4.2 Exposure of Bare Aggregate to Jet Impingement

Water saturated specimens of the three rock samples submitted by your laboratories at Port Hueneme were exposed to the jet blast. One thousand grams of minus 1 1/2 inch and plus 1 inch of each rock sample was immersed in water until saturated (maximum weight). The sized particles of each rock were arranged in screen containers and placed in the jet stream for 10 minutes. The contents of each container was rescreened and the decrease in the average particle size, caused by explosion spalling, calculated. Sixteen percent of the Napa Basalt passed a No. 1 inch screen, 5% of the Juarez Basalt, and 4% of the Napa Quarry. These results were not unlike those obtained on samples tested "as received".

2.4.3 Microscopic Examination

Thin sections of the three rock samples heated at 800°C were prepared and examined microscopically. This examination did not disclose any major change in the minerals present. Oxidation of the iron occurred in all samples. The Juarez Basalt was the least affected by the heating, suffering only a discolorization of the glassy matrix.

2.4.4 Differential Thermal Analysis and Thermal Gravimetric Analysis

A 200 milligram sample of each of two diabases, one from a New York deposit and the second from Virginia, was ground to pass a No. 270 sieve and heated at 6°C per minute

in a DTA-TGA unit. They were maintained at the top temperature for one hour and cooled at the same rate to room temperature. During this test the weight loss (water) of the Virginia diabase was directly proportional to the temperature up to 810°C. The New York diabase underwent an endothermic reaction at approximately 700°C during which a 0.5% loss in weight occurred. Above and below this temperature the weight loss was a linear function of the temperature. The total loss at the maximum temperature, 810°C, was 1.4% for the Virginia diabase and 2.75% for the New York.

2.5.1 Texture of Concrete

In an attempt to identify the open pores in concrete, fluorescene solution was used to penetrate the concrete under vacuum. An 8x8x2 inch concrete panel was placed in a pan that contained a solution of fluorescene one quarter inch in depth. A sponge rubber gasket and an inverted funnel were placed on the top surface of the panel. The funnel was connected to a vacuum pump and evacuated. Some of the panels permitted passage of this solution, and subsequently air, through the top surface in five minutes. Others did not permit the passage of the solution in an hour. The panels were broken and the fractured surface examined. Penetration of the solution was indicated by fluorescence under black light. Penetration was most pronounced in the concrete panels containing an

air-entraining agent and placed by the vacuum process. Lesser penetration was evidenced in evacuated concrete not containing an air-entraining agent, and no penetration was evident in concrete placed by the conventional method. Concretes containing an air-entraining agent and placed by the vacuum process have suffered no loss in the jet impingement test.

2.6.1 Miscellaneous

On instructions from Mr. P. Knoop, of your staff, 1250 pounds of Virginia diabase was shipped to your Port Hueneme laboratory. Seven hundred and fifty pounds of the aggregate was screened through a 1 1/2 on 1 inch; five hundred pounds through 1/2 and 3/8.

2.7.1 Conference

A conference was held at the Bureau on February 20, The names of those attending follow:

P. P. Brown) Melvin Herman) L. A. Palmer)	Bureau of Yards and Docks
C. H. Hahner) R. L. Blaine) B. E. Foster) W. L. Pendergast)	National Bureau of Standards

The object of the conference was to discuss the transfer of the direction of this project from the Refractory to the Concreting Materials Section. Mr. R. L. Blaine is Chief of the latter section. Dr. Foster, his assistant, will direct

the project. A brief review of the work accomplished during the first seven months of the fiscal year was reported and discussed. Topics of study for the next fiscal year were suggested.

U. S. DEPARTMENT OF COMMERCE
Lewis L. Strauss, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards at its headquarters in Washington, D. C., and its major laboratories in Boulder, Colo., is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section carries out specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant publications, appears on the inside front cover.

WASHINGTON, D. C.

Electricity and Electronics. Resistance and Reactance. Electron Devices. Electrical Instruments. Magnetic Measurements. Dielectrics. Engineering Electronics. Electronic Instrumentation. Electrochemistry.

Optics and Metrology. Photometry and Colorimetry. Optical Instruments. Photographic Technology. Length. Engineering Metrology.

Heat. Temperature Physics. Thermodynamics. Cryogenic Physics. Rheology. Engine Fuels. Free Radicals Research.

Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Neutron Physics. Radiation Theory. Radioactivity. X-rays. High Energy Radiation. Nucleonic Instrumentation. Radiological Equipment.

Chemistry. Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Molecular Structure and Properties of Gases. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

Mechanics. Sound. Mechanical Instruments. Fluid Mechanics. Engineering Mechanics. Mass and Scale. Capacity, Density, and Fluid Meters. Combustion Controls.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics.

Mineral Products. Engineering Ceramics. Glass. Refractories. Enameled Metals. Concreting Materials. Constitution and Microstructure.

Building Technology. Structural Engineering. Fire Protection. Air Conditioning, Heating, and Refrigeration. Floor, Roof, and Wall Coverings. Codes and Safety Standards. Heat Transfer.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.

Data Processing Systems. SEAC Engineering Group. Components and Techniques. Digital Circuitry. Digital Systems. Anolog Systems. Application Engineering.

- Office of Basic Instrumentation.
- Office of Weights and Measures.

BOULDER, COLORADO

Cryogenic Engineering. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

Radio Propagation Physics. Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services. Sun-Earth Relationships. VHF Research. Ionospheric Communication Systems.

Radio Propagation Engineering. Data Reduction Instrumentation. Modulation Systems. Navigation Systems. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Radio Systems Application Engineering. Radio-Meteorology.

Radio Standards. High Frequency Electrical Standards. Radio Broadcast Service. High Frequency Impedance Standards. Electronic Calibration Center. Microwave Physics. Microwave Circuit Standards.

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